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ABSTRACT

A global survey was conducted by Unesco in 1986 on the place occupied by the teaching of science, mathematics, and technology, with the data indicating that mathematics and science are firmly entrenched in school curricula worldwide, but the place of technology is much more tentative. It was decided to probe more deeply into the adequacy of these curricula to meet national needs, and to undertake a study of their appropriateness in relation to the rapidly-evolving nature of science and technology. This case study focuses on the 10-year compulsory school of the German Democratic Republic (East Germany). The five sections consider: (1) "General education and mathematics, science, and polytechnical instruction"; (2) "The goals of mathematics, science and polytechnical instruction"; (3) the syllabi for mathematics, physics, chemistry, biology, and polytechnical school subjects; (4) "Teaching method"; and (5) "The preparation of teachers." (MNS)

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Science and Technology in School Curricula

Case Study 3
German Democratic Republic

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Science and Technology in School Curricula

Case Study 3 German Democratic Republic

Mathematics, science and polytechnical instruction in the ten-year polytechnical secondary schools

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Division of Science Technical and Environmental Education

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General education and mathematics, science and polytechnical instruction

Since the late fifties, the ten-year general polytechnical secondary school in the German Democratic Republic (*Polytechnische Oberschule*, or *POS*) has continuously developed as a school for all children following both of the progressive traditions of general education in German school history, as well as the social development in the first socialist German state. The Education Act of February 1965 stipulated that this new type of elementary school should provide a modern, socialist general education as a precondition and a basis for any fur her education and vocational activity. This type of school implements Marx's ideal of the all-round development of socialist personalities, of the combination of productive labour, instruction and gymnastics, and of polytechnical education under the conditions of advanced industry and agriculture in the developing socialist society of the German Democratic Republic.

Socialist general education comprises profound knowledge in mathematics and the sciences as well as knowledge in the social sciences, the mother tongue and foreign languages, in literature and the arts, in physical education as well as in education in the basics of technology and the economy, and of productive labour. By stimulating and developing all the energies and talents of children, by training and educating their spiritual and physical forces, their theoretical and practical skills, their aesthetic senses and feelings, their political, philosophical and moral positions and attitudes, their creative abilities and their character, the polytechnical secondary school creates in adolescents the preconditions for and versatility in complying with the social requirements of the present and future. Yet general education does not end with the student leaving polytechnical secondary school; it is continued in a systematic way both within the process of vocational training and in Forms 11 and 12 of extended secondary schools, which lead to university entrance. The teaching programmes at colleges and universities, too, contain elements of general education, since general education, as comprehensive as possible, is the best prerequisite for accomplishing the various requirements in all fields of social life.

The *POS* is a polytechnical school, where the principles of polytechnical training and education are applied in all school subjects. This means:

Imparting knowledge which is of fundamental importance for science and technology, for social production and for defending one's homeland;

Imparting knowledge of the application of scientific findings for the satisfaction of sociai needs;

Imparting an outline of the foundations and principles of major branches of production and their interaction;

Developing relevant skills for applying methods and procedures of intellectual and intellectual/practical activities which are the basis for the work of many working people;

Inculcating the students' respect for work, enabling them to render purposeful, enduring, careful, reliable and disciplined work and to fulfil social requirements; and

Combining instruction with productive labour in general, and with that of the students in particular, as well as with the life and practice of society's development.

Within the process of polytechnical education and training, perceived as a vital part of general education in a modern society, particular responsibility is laid upon mathematics, science and polytechnical instruction, essential for an understanding of scientific and technological progress in all walks of life. Mathematics, science and polytechnical instruction at the polytechnical secondary school of the *POS* account for about 40 per cent of the total time available for classroom instruction; 41 per cent is alloted to instruction in the mother tongue and in the social sciences, 10 per cent to foreign languages and the remainder to physical education. Due to their fundamental importance in the development of the personality, the bulk of the time is taken by German and mathematics (about 45 per cent of all the instruction time). The experience of the German Democratic Republic over the last few decades has shown that with this distribution of school subjects, a solid general education and an all-round development of the personality can be guaranteed as a basis for any further education, and a satisfactory balance is achieved of the basic areas of general education.

The goals of mathematics, science and polytechnical instruction

The syllabus

The results to be achieved during the instructional process, up to the end of Form 10, are laid down in integrated central syllabuses for each school subject and grade. Worked out with the broad participation of pedagogical scientists, teachers and representatives of the various sciences related to the school subjects, and under the guidance of the Academy of Pedagogical Sciences of the German Democratic Republic they are binding for all schools, and are issued by the Ministry of Public Education of the German Democratic Republic. Constituting a basis for the management of training and education at all levels of the education system in the German Democratic Republic, the syllabuses are also an important prerequisite for the planning of all further education. They ensure that each stage of the integrated socialist education system can systematically link with the previous stage, and that meaningful interaction can be achieved among the various school subjects. The syllabuses of the mathematical, scientific and polytechnical subjects are co-ordinated with each other so that the various subjects complement each other, that one school subject will lay the foundation for another or results of instruction in one subject will be taken up again in another. For example, physics instruction does not start until Form 6, after mathematics instruction has developed the necessary mathematical knowledge and skills. Chemistry instruction, which starts in Form 7, assumes the knowledge of solid, liquid and gaseous substances taught in physics. The preliminary knowledge required for the understanding of the fundamentals of metabolism and energy transformation, which are dealt with in biology in Form 9, are imparted in chemistry and physics. The polytechnical school subjects (school-garden work, handicraft, technical drawing, introduction to socialist production and productive labour) depend upon previous instruction in mathematics and science. Consequently a system of mathematical, scientific and polytechnical instruction emerges which also interacts with instruction in the social sciences.

The goals of the teaching of the mathematical, science and polytechnical school subjects are oriented to the fundamentals of the respective sciences. The subject matter is so structured that students can recognize the relationships between science, technology, production and life, and can understand the fundamental lines of the development of scientific and technological progress and of economic strategy, so that the knowledge they acquire both inside and out of the classroom can become a system of scientific, social and philosophical connections. This integration is implemented by the concerted contribution of all school subjects.

The syllabuses pre-suppose that fundamental knowledge in the various sciences is relatively stable and will not become out of date quickly, despite the speed of scientific progress. For example, the great majority of the applications of physics to technology, agriculture and medicine, even today, derive from classical mechanics, thermodynamics, optics and electricity. The laws of the conservation of mass, of constant composition and multiple proportions or of periodicity are still today of importance to a general knowledge of chemistry, as also are considerations of the relationships of metabolism and of energy transformation. Again, in biology, the function of morphology and anatomy, of the knowledge of species or of the bases of metabolism and energy transformation, are required irrespective of the rapid developments in the biological sciences.

The syllabuses must, of course, also take account of modern scientific trends and developments if classroom instruction is to lead to an understanding of the interrelations between science, technology, production and life, of fundamental trends in scientific and technological progress and of economic strategy. Despite the stability of the fundamentals, new syllabuses must be prepared which preserve the fundamentals while combining them with more advanced requirements.

In the process of the development of the *POS* a comprehensive re-drafting of syllabuses took place in the mid-sixties. Now that these have been in force for some 20 years, new syllabuses are gradually being introduced on the basis of profound analysis of the results so far achieved and of the requirements to be expected during the next few decades. In accordance with the basic trends of socialist general education, the new mathematics, science and polytechnical syllabuses instruction are expected to contribute to achieving greater solidity, applicability and durability of the knowledge of facts, concepts, laws, theories, methods and procedures. At the same time, necessary innovations are coming in. For example, the growth of information technology has led to the need in mathematics for algorithmic thinking, since an algorithmic description of procedures in calculation provides the foundation for computer programming. Physics instruction, among other things, has to impart knowledge of the application of semi-conductors, integrated circuits, optical fibres, radioactive substances and lasers in research, medicine, production and, not least, in uses of nuclear energy. In chemistry instruction, such issues as the use and processing of domestic and imported raw materials and

of re-cycled materials, of applying procedures which are low in waste products and closed circulatory systems, as well as the inter-relations between the economy and environmental policy, all have to be dealt with, without neglecting the classical foundations. In biology instruction, the basics of ecology and of biotechnology will be treated in greater depth than hitherto. In polytechnical instruction, the treatment of electrical engineering and the automation of production will bring to the fore the information technology of the production process.

The introduction of the new syllabuses started in the early eighties and will be completed by about 1990. They will provide the basic mathematical, science and polytechnical instruction needed to carry education into the next century, while preparing the next generation in the best possible way for the tasks facing society in the coming century.

Mathematics

Mathematics instruction seeks to impart profound knowledge of the fundamental concepts, theorems, rules and procedures of mathematics. The students should become skilled in arithmetic, drawing and constructing. So equipped, and with sound thinking and working methods, they must learn to perform tasks on their own. Successful instruction in mathematics has a significant influence on the development of personality and on the standards reached in science and polytechnical instruction as well as on further training and education. Mathematics, therefore, with its five to six periods per week (totaling 1,600 periods in ten years) is an essential component of education throughout secondary school. Achievement in mathematics is also significantly influenced by the growing use of mathematical methods and procedures in the sphere of material production. Increasingly, situations, tasks, processes and problems are being cast into mathematical form, and treated and solved with the help of mathematical methods. Sometimes, entire production processes are organized and operated by suitably programmed computers. This development must be taken into account in the general secondary school if it is to prepare the students for the future realities of life.

An imperative aim of mathematics instruction is to ensure a command of calculation, for this is an essential prerequisite for further progress in the subject. Consequently, by the end of ten years of schooling, the students will be able to work reliably with variables, correctly transform formulae, and solve equations (linear and quadratic, systems of two linear equations with two variables) and linear inequalities. At all times, attention is paid to achieving a good balance between mental and written calculation and the solving of problems with the help of a pocket-calculator. Command of calculation also includes approximation and the estimation of error (absolute and relative). When operating with equations and inequalities, students of all grades should be familiar with a content-oriented approach to solutions and with the possibility of different sets of solutions. Wherever it is convenient, students should give evidence of their command of the technique for solving linear and quadratic equations. In this context, algorithmic training is essential since this links with information technology. So flow diagrams are often used in work with the pocket calculator. It was previously stated that algorithmic descriptions of calculation are a basis for working with data-processing hardware. This is also true of operating with variables, the mathematical modelling of facts and the exact use of mathematical terminology and symbols.

Set theory considerations apply to mathematics instruction in so far as they help to enlighten teaching and the students' cognitive perceptions. However, set theory, as such, does not explicitly appear as subject matter. Consideration of sets and relations between sets range from material objects to sets of abstract mathematical objects. Up to Form 10, for example, the number concepts range from the set of natural numbers up to the set of real numbers. While students know the structure of fractional and rational numbers relatively extensively, the nature of real numbers is explained only briefly. In addition to command of calculation in all number ranges, the concept of a function has a dominant place in mathematical education. Students should have a command of linear and quadratic functions, power functions, exponential functions and trigonometrical functions and be able to use these functions to solve simple mathematical and practically relevant tasks. A basis for understanding functions is laid right from the beginning of the first year, and eventually functional thinking is developed to such an extent that, by the end of Form 10, the students are able to investigate relevant functions and classes of functions independently.

In the context of geometry, the students learn the fundamental concepts, the theorems and the construction procedures of planimetry, stereometry and descriptive geometry and their applications. They also learn how to formulate concepts and theorems and how to discover and carry out proofs. The students discover and carry out simple proofs such as proofs of congruency independently. In this context, they learn to use theoretical rules, principles and procedures (such as constructing auxiliary lines), applying the principle of re-conversion, concluding forwards and backwards.

Another aim of the mathematics course is to develop the students use of language so that, in addition to fluency in the mother tongue, exact mathematical formulations become a regular part of their use of language. The students must learn to formulate, or describe, definitions and mathematical theorems and

procedures in correct language. The ability to reformulate statements in logically equivalent statements with elements of standardized speech is also striven for. This training of language skills illustrates an important interdisciplinary aspect of general education.

There are certain features of the mathematics instruction which appear at all levels. These include the following:

Concepts, statements and definitions as, for example the concept of a 'rational number', the statement '2 is an even number', the theorem of Pythagoras, the definitions of 'trapezium' and of 'parallelogram';

Methods and procedures which embody essential elements of mathematical method, such as the rules for calculation in various number ranges, the rules for solving linear equations, the methods of concluding and of giving a proof, the procedures for solving problems and the working principles of heuristics; and

Philosophical, political and moral ideas such as an elementary insight into the essence of mathematical concepts and methods, conclusions about the relationship between mathematics and objective reality, or social practice, and conclusions from the development of mathematical science, from the increasing role of mathematics for social development, and from the application of mathematics to the national economy.

The interpretation of subject matter in this way shows very clearly that by imparting knowledge, developing abilities, providing philosophically important insights and shaping attitudes and character traits, mathematics instruction, like instruction in all other school subjects, plays a valuable role in the all-round education of the personality.

Physics

Within the framework of the general objectives of socialist general education, physics instruction aims mainly at imparting exact and applicable knowledge of fundamental physical facts, concepts, laws and theories, the command of which provides the foundation for understanding phenomena and processes in nature, technology and production; enabling the students to apply scientific thinking and the working methods of physics; imparting the fundamentals of a scientific world outlook, and the essential conceptions of dialectical and historical materialism; and promoting those moral and character features which are important for living in a socialis. society.

Physics instruction in Forms 6 to 10 is so structured that with two or three periods per week (a total of about 390 periods) the specific aims of instruction can be achieved step by step.

The students acquire fundamental knowledge from mechanics, thermodynamics, electricity, optics, and atomic and nuclear physics.

In *mechanics*, the students learn the basic concepts and laws of kinematics and dynamics. They learn the laws of kinematics for steadily and evenly accelerated motions and can apply these laws in calculations on moving bodies. With the help of Newton's Laws, they are able to explain processes in nature, technology and production, and to predict phenomena. The introduction of the physical units of mechanical work, power and energy, as well as of the law of the conservation of energy, provide the basis for solving practical significant tasks, as well as for explaining phenomena.

A further aspect of mechanics is imparting the fundamentals of hydro and aerodynamics. Dealing with the concept of pressure, the transfer and combination of forces, the use of buoyancy and the reduction of resistance imparts the elementary principles of operation which are the subject matter of classical physics and of great importance for technology and production.

A third feature of mechanics is dealing with oscillation and waves. The main interests here are the physical units which describe oscillation and waves. Other phenomena dealt with are reflection, refraction, diffraction and interference of waves, all of which are both theoretically and practically important.

In *thermodynamics*, attention is paid to two important phenomena. The thermal behaviour of bodies and substances is the first. Here, the centres of interest are the fundamental concepts (temperature, heat and thermal energy), and understanding changes in volume and in the lengths of bodies with changing temperatures, as well as changes in the state of matter, together with typical applications of these behaviours in technology and production.

Conversion, transfer and conservation of energy in thermal processes constitute the second aspect of thermodynamics. The students acquire knowledge of the first and second theorems of thermodynamics and of the efficient use of energy in technology and production. The subject also deals with important fundamentals for the understanding of the conversion of energy and matter in chemical reactions and in life processes.

Electricity and magnetism covers four main elements. In discussion of direct current, students learn the concepts of charge, current, voltage and electric resistance, as well as the laws of branched and unbranched electric circuits. They learn about the emergence and practical importance of electrostatic and magnetostatic fields and can give the relevant descriptions. Dealing with the processes of electric flow in various media leads to knowledge of the physical processes of electric conduction in metals, liquids and gases, in a vacuum and in semi-conductors. Thus the students come to understand the fundamentals of modern technology.

In discussing alternating current (A.C.), the students learn the laws of induction and Lenz's Law. They also learn about self-induction and eddy currents and their significance. As examples of the applications of electromagnetic induction, the students meet the A.C.-generator and the transformer. In addition to this, knowledge is imparted about the behaviour of ohmic components, coils and capacitors in an A.C. circuit.

After becoming familiar with electromagnetic oscillation and waves, the students learn about the generation of electromagnetic oscillations and about transmitting and receiving Hertzian waves, as well as of some important properties of Hertzian waves. They are also given a general view of the electromagnetic spectrum.

At the centre of *optics* are the concepts of radiation and waves, as well as some ideas of quantum optics. In the context of radiation, students meet the spreading of light, reflection, refraction, the formation of images with mirrors and lenses, and the construction of optical instruments. Wave optics acquaints the students with the wave properties of light (diffraction and interference) and of spectra and their importance. Reference to the application of lasers and their properties provide the students with an outlook on a field of radiation which is of great significance for modern technology.

With regard to *atomic and nuclear physics*, attention is mainly paid to nuclear physics. The students are aware of the structure of atoms and of elementary particles as the fundamental components of nature. They are acquainted with natural and artificial radioactivity and they acquire knowledge about the different kinds, the properties and the effects of nuclear radiation, as well as about nuclear fission and nuclear fusion.

The imparting of knowledge is inseparably linked with teaching the students to apply scientific thinking and working methods. By the end of their physics course, students should be able to carry out independently activities relevant to physics such as describing and explaining facts and states, predicting phenomena and processes, interpreting equations and diagrams, planning, carrying out and evaluating experiments, and solving simple physical tasks.

In developing experimental skills the students learn to determine the units which are important for physics and to evaluate critically physical measurements; plan, carry out and evaluate experiments as questions addressed to nature; and investigate experimentally the mode of operation of technological objects.

Enabling the students to apply mathematics is aimed at understanding how with the help of mathematics, physical units can be defined and their laws be derived; the physical content of sets of measurements can be depicted in the form of diagrams and equations, with the help of mathematics; and physical problems can be solved with the help of equations and diagrams.

The close connection with mathematics exemplifies how physics interacts with other school subjects. Physics contributes greatly to consolidating mathematical knowledge and skills by application. But it is also closely related with chemistry and with the polytechnical subjects. As in mathematics, physics, too, plays an important part in the development of clear, logical and unambiguous language.

Chemistry

POS chemistry instruction is designed for close integration with mathematics, physics and the polytechnical school subjects, as well as with social science. In particular, it aims to convey elementary insights into the structure and properties of substances and of the conversion of matter. The main determinants of the content of chemistry instruction are: the relationships between the structure, physical and chemical properties of substances and their application; the unity of conversion of both matter and energy in chemical reactions; and applications of chemical substances and reactions in technology and production.

On the basis of these main trends, the students of Forms 7 to 10 are acquainted with fundamental laws of the structure of substances, the process of chemical changes, important fundamentals of chemical production, as well as the application of chemistry in other fields. The subject receives two or three periods per week, making 270 periods in all. The understanding of the fundamental laws of structure and of chemical reaction effectively supports the formation of a scientific world outlook and an understanding of the value of chemical science for the well-being of man. The links forged with the subject matter of other subjects promotes a comprehensive view of phenomena in nature and society.

After their first few lessons on the *structure of matter*, students are able to differentiate between metals, molecular substances and ionic substances as fundamental classes of substances, which are completed later on by the class of polymers. In further lessons, other substances can be allotted to these classes according to their structure. Structure, of course, is not discussed in isolation; the characteristic properties of substances and of classes of substances as well as possible applications of these substances or the consequences of handling them are also considered.

At the end of the chemistry course, students know about the fundamentals of chemical bonding. They can differentiate between atomic bonds, including polarized atomic bonds, ionic bonds and metallic bonds, and can relate the kind of bond to the property of the substance. The students are made familiar with the structures and phenomena of substances which are on the one hand relevant to the classification of

substances and on the other of great importance to the national economy. This holds for selected metals, substances which are made up from elements of the IVth, Vth, VIth and VIIth main groups of the periodic table, as well as selected organic classes of compounds such as aliphatic hydrocarbons with single and multiple bonding in the molecule, organic compounds with functional groups in the molecule (alkanols, alkanes, alkanic acids, amino acids, esters and fats) and macro-molecular substances as a sub-class of polymers. The students know that the structures of organic substances are basically determined by the same laws as those of the inorganic ones, and they therefore can also work out relationships between the structure and the reaction of organic substances.

The students recognize the periodic table of elements as a theoretical foundation and a working tool. They can work out the relationship between atomic structure and the position of the elements in the periodic table and can infer the essential properties of particular elements from their position in the periodic table. Already, during the first few chemistry lessons, the students are acquainted with the fact that *chemical reactions* always involve a unity of conversion both of matter and of energy, and that chemical reactions are always accompanied by physical processes. They also learn, at a very early stage, that man harnesses chemical reactions more and more for the satisfaction of his needs.

Until the end of Form 10, the students are learning about chemical reactions in an elementary (primarily phenomenological) way. They know that the kind of reagent, the intensity of intermixing the parent substances, concentration, temperature and, in the case of gases, pressure have an effect on the course of a chemical reaction. They know about chemical equilibrium and, with the help of this knowledge, are able to make predictions on the course of simple reactions, to explain phenomena connected with chemical reactions, or prove statements on chemical reactions. Basic types of reaction which the students know include reactions with a transfer of electrons and also substitution, elimination, addition, polymerization and polycondensation as important types of organic reaction.

Elementary quantitative considerations, too, are important to the understanding of the nature of chemical reactions. Using their knowledge of the law of conservation of mass, of the fundamentals of chemical symbols and of the relations between particle, mass, and quantity of substance, students can carry out simple calculations of parent substances or reaction products of chemical reactions.

As they go more and more deeply into the structure of substances and the nature of chemical reactions, students become acquainted with the *technological application of substances and reactions*. In learning about the production of pig iron, copper, aluminium, caustic lime, methanol, ammonia and sulphuric acid, and the processing of coal and of mineral oil, they see how technology and industrial production make use of what is known about substances and chemical reactions in order to produce useful products from available materials. Chemistry thus imparts basic knowledge about the major industries of the German Democratic Republic. Students also acquire knowledge about the application of chemical science in other branches of production and spheres of life, as well as about the interrelations between the chemical industry and other industries. Chemistry thus promotes the emergence of an understanding of economics, of the unity of economic and social policy and of the policy on the protection of the environment. The students, however, also come to recognize the need for personal commitment in applying chemistry to the well-being of human beings.

Biology

When systematic biology teaching starts in Form 5, the students have already made a comprehensive survey of the fauna and flora of their home region in the local history and geography lessons at primary school. They know the most important species of animals and plants in their vicinity. They also possess some basic facts about the environmental conditions of plants and animals. They know that nature has to be protected and cultivated. They have, as well, some basic knowledge of how to live healthily.

Biology instruction in Forms 5 to 10 involves about 330 teaching periods. It deals with the following themes: the structure, biological circumstances, environmental relationships and significance of vertebrates; the structure, biological circumstances and significance of spermatophytes; the cell; unicellular animals and invertebrates; fungi; bacteria and blue-green algae; non-flowering plants; the anatomy and physiology of man (metabolism and energy conversion sensorial and nervous functions, hormones, reproduction and individual development, body posture and movement); plants and their biological circumstances; the relationships between organisms and environment; heredity; and phylogeny.

Instruction about vertebrates, spermatophytes, unicellular and invertebrate animals, fungi, bacteria and blue algae or non-flowering plants always includes evolutionary and ecological aspects. Initial basic knowledge of biotechnology is imparted in dealing with fungi, bacteria and blue algae. This is then expanded when human anatoma and physiology is taught in Form 8 and immune and enzyme technologies are dealt with. In Form 10, the knowledge about biotechnologies is then co-ordinated and systematized.

At the end of biology instruction in the *POS*, the students have a profound knowledge of structure, occurrence and behaviour of organisms, about their living together in ecological systems and about their

adaptation to the environment. They know the fundamental features and laws of the biological circumstances of the organisms and of applications of biological findings. During instruction, the students come to understand the connections between cell, tissue, organ, organism and communities of organisms as well as between biological objects (organism and ecological system) and their environment. They know that the processes of life such as metabolism and conversion of energy, reproduction and heredity, and ontogeny and phylogeny of organisms are linked to particular structures.

In the course of biology instruction, the students recognize the similarities between man and other mammals in fundamental biological circumstances as well as his peculiarities. Using well-established genealogical knowledge and vivid ideas of genotypes of organisms and of the relations between organisms and environment, the students learn the fundamental concepts and laws of biology and their practical applications. They know that all life processes are characterized by the action of biological, physical and chemical laws, they become aware that man has consciously, for thousands of years, been using organisms and sets of organisms for satisfying his needs. From examples of animal husbandry and crop cultivation, of foodstuffs and forestry, of medicine and environmental protection the students learn to appreciate the role of biology and biotechnology in developing the national economy of the German Democratic Republic. They learn about purposeful changes in the biological make-up of organisms and, consequently, in their efficiency by virtue of breeding, manipulating genes and purposefully altering their environmental conditions through the application of biological findings. The practical orientation of biology instruction conforms with the requirements of a developing socialist society, where both work and other social activities increasingly rely on scientific findings.

In the process of learning about structures, processes and interconnections in living matter, the students systematically learn the methods and procedures of biology. Biology instruction, in particular, helps the students to make the observations necessary for the classification of biological objects according to their essential features, to understand structures and life processes, and to recognize the development of biological objects. Observing is always closely linked with other activities such as dissecting, defining plants and animals, using dissecting instruments, the magnifying glass and the microscope. In close harmony with the teaching of physics and chemistry, the students' ability to prepare, execute and evaluate observations and experiments independently is developed. This includes the students' education for careful, systematic and enduring work, and for a factual and unprejudiced evaluation of the results of work.

In addition to the acquisition of a scientific system of concepts and statements, the unity of the empirical and the theoretical paths to knowledge, of theory and practice, of science and ideology, a scientific world outlook also emerges. By delving into the laws of the phenomena of life, during a course based on observation and experiment, the students become convinced of the objective character of these laws of nature and learn to recognize them. The students also recognize that life on Earth has developed from non-life, and that today's living organisms are the result of a very, very long evolutionary process, which also includes the development of man from the animal kingdom.

In biology, the students learn to respect and preserve living nature, to preserve their own physical health and performance and to devote these to the protection of the environment. With examples of human influence on the performance of organisms, the students realize that techniques are being developed which lead to new possibilities for producing materials and preserving the environment.

Polytechnical school subjects

In polytechnical instruction, the students acquire the knowledge they need for the execution and understanding of socially-useful and productive work. Gradually they learn to understand fundamental technological and economic concepts and laws which are important for the development of versatility, the formation of all-round vocational interests, for education in socialist labour and preparation for vocational training. Such knowledge, in combination with knowledge of mathematics, science and social science, provides a survey of the important areas of production and thus contributes to a balanced general education and to shaping the students' scientific world outlook. In addition, the students develop practical abilities and skills.

Polytechnical instruction starts at primary school level (Forms 1 to 3) with handicraft and work in the school garden. At intermediate school level (Forms 4 to 6), instruction in school gardening is continued. The greatest amount of time, however, is devoted to handicraft in Forms 4 to 6. At secondary school level, (Forms 7 to 10), the demands on students are gradually raised. Here, technical drawing and an introduction to socialist production and to productive labour determine the content of polytechnical instruction. And this is always closely associated with the science subjects.

In a total of about 100 periods of *school gardening*, the students learn how man can promote the growth of plants by his own activity, by suitable soil preparation, proper tillage, proper cultivation, irrigation and fertilization. In an elementary form, the students are thus introduced to scientific interconnections and to their utilization for practical work. By the end of Form 4, students are able to use simple tables and

mathematical procedures. They know that good quantitative and qualitative results can only be achieved through careful, diligent, conscientious and skilful work.

In the *handicraft instruction* of Classes 1 to 3, the pupils make useful objects. They learn how to measure, check, mark out, cut and join materials such as paper, cardboard, plastic sheeting and imitation leather. They use elementary tools, they become accustomed to organizing their work, and they take pains to keep the workplace tidy.

When making models, the pupils learn the modes of operation of machines and the technological components and modules, and how to use them for the solution of technological problems. They thus acquire important initial knowledge of engineering and become familiar with concepts which will later be used time and time again (e.g. screw, nut, adjusting ring, tool, roller, rope and lever).

Handicraft in Forms 4 to 6 uses wood, plastics and metal. The students learn how to operate elementary machines and devices (e.g. the pillar drilling machine and bevelling and bending tools). By the end of Form 6, they are able to decide which tools to use for the materials used, and whether such procedures as shaping, cutting and joining are to be applied. The practical activity of students is, time and time again, determined by the three main phases of the working process: preparation (planning the steps of the work, choosing the tools and materials and reading and drawing simple sketches), execution (sawing, filing, drilling, glueing, nailing, riveting, bevelling and bending, as well as surface treatment) and checking (using the steel rule and slide-rule and checking angular accuracy).

During work with engineering kits, students are systematically enabled to find (with increasing independence) solutions for simple engineering tasks and to design, make and test a model. They acquire elementary knowledge in mechanical and electrical engineering. Attention is paid in the main to the purpose of simple devices and equipment, instruments and machinery, how they work and how they are used. The students know the applications of electrical energy and the possibilities of adapting working and driving movements with the help of elementary gears.

For handicraft instruction at primary school level a total of about 100 periods is available, and at intermediate school level about 180.

In *technical drawing*, the students of Forms 7 and 8 learn to read drawings and to make sketches and simple drawings. The total time available is about 60 periods, or 1 period per week. Students acquire a basic knowledge of: the orthographic projection of objects; oblique frontal dimetric projection; how to enter measurements in a drawing; applying scales; the interrupted projection of objects; sectional projection; thread representation.

The students practise the application of known procedures for making sketches and drawings, as well as designing. They acquire the skills of describing the shapes and sizes of depicted objects, transforming one kind of projection into another and drawing an individual component from an overall drawing. In technical drawing, concepts of design and function are developed, and technological thinking is promoted as a whole. The students become accustomed to working accurately and tidily. They learn to understand a technical drawing as means of international communication and thus acquire the important fundamentals for the introduction to socialist production and productive labour.

In the introduction to *socialist production* (within a total of about 180 periods) the students delve more deeply into the laws of working life. In Form 7 (1 period per week), the students are introduced to fundamental technologies such as founding, rolling, lathing, joining and coating, as well as efficient industrial applications of these. The important processing properties of materials are taught and incorporated into a complex consideration of procedures, work tools and objects, as well as the economic aspects of technological processes.

In Form 8 (1 period per week), the students become better acquainted with machines as the most important tools of modern production. They learn the general principles of machines, their operational components and their co-ordinated action. They learn to depict graphically the co-ordinated action of these operational components in the form of a block diagram. They read and draw projections of gears. They evaluate diagrams of elementary technological processes and eventually can determine, from an economic point of view, the best use of various instruments.

Instruction in Forms 9 and 10 (2 periods per week) focuses on the information side of the production process. In electrical engineering, the students learn about electro-technical and electronic production instruments, components and circuits. Electrical information engineering concentrates on obtaining, processing and using information with the help of electrical signals in the production process. The students are made familiar with elementary logic circuits and their technical implementation with the help of the relevant components and integrated circuits. They also encounter the use of highly integrated circuits for the automation of production processes. As to knowledge and skills, the syllabus specifies such mental and practical activities as: describing the operation of a circuit; connecting and testing a circuit; finding errors in circuits and their causes; measuring voltage, amperage and resistance and calculating output; connecting and testing circuits for basic logic functions; setting up a photo-electric control, with threshold level switch; demonstrating the flow of information in signal-flow diagrams; building analogue and digital controls;

developing, building and testing models of an assembly-line control; and building and testing the model of a numerically-controlled machine-tool.

Within its context, the introduction to socialist production is oriented to social needs in an era of scientific and technological progress. This raises questions of efficiency of production in manufacturing, in construction and agriculture. It thus promotes the understanding of the unity of economic and social policies in the German Democratic Republic. It also relates closely with instruction in the social sciences.

At present, the introduction of a basic course is being prepared for work with computers. This will take up 40 periods and include the following: an introduction to work with a computer, the fundamentals of programming, the processing of data with the help of a computer and applications of computers.

This course can rely on the algorithmic thinking developed in the mathematics course and illustrates how education adapts to advances in science and technology.

All-round education in our socialist society is imperatively linked with the development of an ability and a readiness to participate in work, the basis of human life. In *productive labour* the students are gradually brought in touch with working people. They are introduced to the reality of life and of working conditions. They experience the achievements of progress in science and technology and how these are used to develop a socialist society. Teaching in school is enriched with practical experience. The work the students do in the factory becomes the application of previously acquired knowledge and skills. Productive labour is a way of combining theory and practice in the socialist school. Under the guidance of skilled workers, the students learn about work; they acquire the skills of work, working habits and work experience. For more than 25 years, this school of life has proved itself in many ways.

Productive labour in Forms 7 and 8 (2 periods per week) concentrates on machines and on the manual processing of materials, as well as on simple assembling, dismantling and completing work. The formation of working knowledge and skills is linked with the production of goods which are needed in the factory or elsewhere. The students become accustomed to plan and prepare work, to work conscientiously and to check the results of work. Those students who are trained in agriculture acquire elementary skills of soil cultivation, animal husbandry and plant production. Depending on their knowledge of the work and the skills achieved, students also participate in production proper.

The productive labour of Forms 9 and 10 (3 periods per week) involves actual production. Side by side, and in co-operation with working people, students fulfil the production tasks of the particular enterprise: operate, supervise and maintain machine tools and other machinery. They help in repair work and with assembling jobs. They also carry out special tasks. Employment is decided on the basis of regional conditons. The plans for productive labour offer the following specializations: metal-working industry; electrical engineering/electronics; agriculture, forestry and foodstuffs economy; maintenance and servicing of agricultural machinery; chemical industry; textile industry; garment industry; wood-processing industry and leather goods industry.

Regardless of the territorial differences in the students' employment, the same basic guide-lines are valid for all students in all areas. With this training in productive work, industrial and agricultural enterprises have assumed a considerable responsibility for the young generation's education, and they comply with these tasks with increasing quality.

A fundamental principle of the polytechnical secondary school in the German Democratic Republic is that of *the combination of classroom instruction with productive labour* from the first to the last day at school. This is implemented in various ways. Firstly, it is implemented by the very organization of education, that is to say by the fact that productive labour, as such, forms part and parcel of instruction in the higher grades, and that the students directly participate in material production for the purposes of training and education. As early as the primary and intermediate levels, even the youngest students make useful products in handicraft and school gardening and thus participate, according to their powers and abilities, in material production.

A second aspect of the combination of classroom instruction and productive labour is manifest in the increasingly comprehensive application of what is learnt in the natural and social sciences to school gardening, handicraft and productive labour. The students apply more and more their theoretical knowledge to practical work. They thus experience the unity of theory and practice, and increasingly comprehend the use of theoretical knowledge for fulfilling practical tasks.

A third aspect arises from the second, because, in the traditional school subjects, the principle of polytechnical training and education is being implemented and so these subjects impart the scientific foundations of social life and of the most important branches of social production. The students are acquainted with important methods and procedures of intellectual and practical activities and the foundations of science are always linked with social practice.

A fourth aspect of the combination of instruction with productive labour is that social and natural sciences take advantage of the students' work experience and relate it to theoretical foundations. Even at primary level, pupils can use experience from school gardening in local history and geography or solve tasks in mathematics which are relevant to handicrafts. Mathematics and physics instruction uses the students'

experience from handicraft or productive labour in various ways for relating instruction to real life. In chemistry and in biology, the teacher in a rural school, where students have experience in agricultural production, will link this experience to each subject and so combine classroom instruction with productive labour.

Training and education in the *POS* is aimed at the optimum development of children and youth. This means promoting and unfolding all the powers, dispositions, talents and interests. There are many opportunities for the differential promotion of talents and interests, when teachers work on the principle of responding to students individually. Experienced teachers can challenge certain students by assigning them tasks which go beyond the requirements of the syllabus or alternately introduce further studies to deepen students' knowledge and skills. This is called *inner differentiation*, because it takes place within the context of obligatory instruction. Of course, the possibilities of inner differentiation are limited. In the course of the development of the *POS*, various optional forms of training and education have been established. Work and interest groups under the guidance of subject teachers or experts from enterprises offer the students the opportunity to follow their own interests and inclinations and to acquire specialized knowledge and skills. During the seventies and eighties optional courses for students of Forms 9 and 10 have increasingly become an integral part of the training and education offered by the *POS*, providing opportunities to expand, perfect and deepen the knowledge and skills developed in the obligatory courses. They constitute a form of *outer differentiation* of instruction because they are outside obligatory instruction. Such optional courses are offered in all subjects at the *POS*, conditioned by the available material and personnel at each particular school. The courses are run by subject teachers or by experts from enterprises and institutions. Within the present system of mathematical, scientific and polytechnical school subjects these optional courses are offered in:

Mathematics:	practical mathematics, working with sets and elementary statistics;
Physics:	electronics and technological applications of physics;
Chemistry:	the chemistry of metals, chemical technology, applied chemistry (chemistry of water and chemistry of mineral oil) and agrochemistry;
Biology:	microbiology, soil fertility and socialist nature conservation (use and protection of the environment);
Technology:	the building industry, motor-vehicle engineering, cookery (serving and servicing), sewing and machine knitting, technical repairing, animal husbandry and fodder production.

As a rule, students select one of the courses (which is run for 2 periods a week) and attend the course during Forms 9 and 10. Participation is voluntary. It is expected, however, that all students will participate in one course. At present, 80 to 90 per cent of the students of Forms 9 and 10 take optional courses.

A survey of the themes of optional courses in the fields of mathematics, science and polytechnical instruction has already shown that in this area the principles of polytechnical training and education have been upheld. In optional courses, too, the all-round development of the personality is aimed at: they promote knowledge, intellectual and practical abilities and skills, and the ability of and the need for independent learning; the students are enabled to apply their knowledge and skills with practical relevance; they promote the unfolding of the creative powers, of independence, activity and self-responsibility; and they support the emergence of interests and inclinations, of attitudes and modes of behaviour.

Optional courses, because of their flexibility, also offer the possibility of including new discoveries in of science and technology, and to relate closely learning with social practice.

Teaching Method

As far as teaching method is concerned, the teachers of mathematics, science and polytechnical instruction can rely on progressive experience, in particular on the experience gained during more than forty years of scientifically-oriented subject instruction for all children of the people. All the institutions concerned with the administration and management of public education, the Academy of Pedagogical Sciences of the German Democratic Republic, and pedagogical and methodological journals, as well as German Democratic Republic Television constantly propagate the best of the methodological experiences. Developed in conjunction with educational psychology, the methodologies of the various school subjects have become solid and effective academic disciplines over the last few decades. They have also laid the foundation for the kind of method of teaching that guarantees that almost every child is successfully guided to the objectives stipulated in syllabuses.

The teaching method is determined by the aims and content of instruction in the ten-year school. The general aim of educating young people who are to become active and successful in dealing with their environment and to engage creatively in the solution of problems of social development, can only be if the students engage in a wide range of activities and thus develop their intellectual powers. The way in which instruction is guided must also develop the students' ability and their capability for further learning, and enhance their knowledge and skills, even after they have left school. Whenever possible, mathematical, science and polytechnical instruction will ensure that, under the teacher's guidance, the students grasp concepts through independent activity and gain insights which are important for their future. Within the framework of this paper, it is not possible to give more than a brief survey of the methodological diversity of the various school subjects. Nonetheless, a few typical examples are offered.

In mathematics instruction, for instance, the elaboration of algorithmic rules plays an important part in the process of learning mathematical procedures. Here the students come gradually to understand how to learn such rules in the various fields of mathematics. During the elaboration of algorithmic rules, the students will find a solution, as independently as possible, by analogy and by combining the known with the unknown. In each of these cases, the following steps are necessary:

The students are introduced to the nature of the problem. Its particularities and its relationship to other problems are discussed. For example, the students will at first attempt to solve an equation by intuitive reflection, or they will look for solutions by trying out particular rational numbers.

The algorithmic rule is then found by generalization, by reflecting about previous procedures and expressed in a very short form, which must, however, be understood by the students. The students will then formulate the rules for solving a particular type of equation or for the addition of rational numbers.

The newly discovered algorithmic rule is then applied by the students to solving similar problems. For instance, they solve equations according to the new rule, or they will add rational numbers according to the new rule of calculation.

Of course, not all mathematical concepts, statements or rules can be discovered independently by the students themselves. Often, it saves time if the teacher provides the necessary information. Acquisition then takes place through intensive work in, say, solving similar problems.

Mathematical method believes in the effectiveness of 'guiding tasks', complex routines for tackling larger sections of content which, for the students, amount to their strategic orientation. The work required in such guiding tasks is not only directed towards the specific mathematical objective; it also aims at general educational intentions beyond the particular mathematical task. Guiding tasks help the students to understand the aim of the work. They motivate the students to tackle the problem. Guiding tasks must be designed to assist the discovering of fundamental procedures for the solution of particular tasks. They will help the pupil to devise his own work plan and provide the mathematical means for implementing the plan. Within some guiding tasks, several partial tasks are given. These assist the pupil to reach a solution and they impart or reinforce previous mathematical knowledge. This technique underlines the fact that it is not only the selection of subject matter and its arrangement but also the method of teaching that imparts mathematical knowledge, develops mathematical skills and promotes personal develop through the unity of training and education.

In the science subjects, method is dominated by observation and experiment. The syllabuses for chemistry in Forms 7 to 10 stipulate eighty demonstrations and eighty students' experiments. The syllabuses can therefore only be fulfilled if the experiments are actually carried out in class. In this respect, the syllabus provides a certain orientation towards the method of instruction. All schools are now provided with the means for doing experimental work in science. Most schools have specialized classrooms for the various

science subjects equipped with all the necessary facilities. Experimental work in science aims at the following:

An experiment acts as a route to cognition, as a source of information about objects and processes and as a means of verifying theoretical statements. It thus serves as an important means of developing a scientific world outlook.

In the course of experimental work, the students become familiar with the basic modes of scientific work. They learn how to investigate natural phenomena and how to formulate reasoned statements about them.

In the process of experimenting, the students develop practical abilities. These, in combination with polytechnical school subjects, are an important preparation for vocational training. The students exercise their minds and their hands.

Finally, experimenting makes high demands on attitudes and character qualities and so promotes them, thereby helping to develop the adolescent personality.

Experimental work in science is closely linked with learning the concepts and the laws. With the help of experiment and observation, the students, in the course of more or less independent activity, gain information about objects and processes. This then helps them to understand the laws and to link this new knowledge with previously learned subject matter. In physics in Form 6, for instance, the influence of forces of different strengths on the changes in the length of a spring is found by experiment. The students compile the gathered data in a table of measurements and graph them. Demonstrating considerable independence, they then can formulate the general statement that doubling the acting force causes a doubling of the change in the length of the spring, while tripling the acting force causes a tripling of the change in length, and so on. This shows that the experiment serves as a source of cognition because the students collect and evaluate information through carefully studying a phenomenon under changing conditions. Practical and mental activities are closely linked.

The demands on experimental activity by the students are being increased from year to year as they gain in experimental experience and penetrate more deeply into the theoretical foundations of the sciences. In the chemistry instruction of Form 9, for example, the influence of the size of alcohol molecules on the reaction behaviour towards alkaline metals (such as sodium) has to be investigated. With the help of a demonstration experiment, the students recognize that methanol reacts faster with sodium than does propanol. A comparison of the molecular structures of methanol and propanol, in connection with the experienced intensity of the reactions on the one hand, and remembering the connection between molecular size and the properties of alcohols on the other, can lead the pupil to the assumption 'Maybe we can say: the larger the molecules of an alcohol, the less vigorous will be the reaction with sodium'. Thus, with relative independence, the students can arrive at a scientifically reasoned hypothesis which, however, has still to be verified by the test to determine whether this discovered law is also correct for reactions with other alcohols. In this case, the students' experience – and they have an active share in creating this experience – serves at first as a source of cognition, then as a way of testing an assumed law derived from observing the first two experiments. The methodological procedures in the above examples from physics and chemistry can analogously be applied to numerous similar situations in science instruction.

Apart from many other learning activities, the observation of natural objects is of great importance in biology. There, the students are led to find results by directly and purposefully dealing with the object in question. Of course, the decision whether and how an observation is to be carried out will depend on the educational objective and on the nature of the object. For example, observations are carried out of plants or parts of plants (leaves, twigs, buds, fruits and seeds) or animals or parts of animals (skulls, sets of teeth, parts of the skeleton, samples of skin or fur, feathers and shells). Often comparative observation of various objects is practised as this is important for the elaboration of biological concepts or the understanding of taxonomic and biogenetic interconnections. By determining plants and animals with the help of simple classification tables, the students practise comparative observation too. The students also observe various biological processes, for example, food intake by fish, respiratory movements of humans, sensory reactions of the earthworm, processes of the development of insects. Often observations are carried out on objects which have been dissected with the help of scissors, a scalpel, a razor blade etc. For microscopic work, the objects are processed into preparations. These operations are often linked with specific working procedures. In Forms 5 to 7, the anatomy and physiology of organisms are observed and explored, mainly in the course of dissection. In Forms 8 and 9, primarily ecological and physiolocal processes are observed. Such observations, of course, require certain material preconditions. These put high demands on the quality of the teacher's guidance of instruction.

As pointed out earlier, unity and interaction of intellectual and practical activity also determine the instructional process in polytechnical school subjects.

The preparation of teachers

The short introduction to the aims and content of the various school subjects, and the discussion of a few aspects of teaching methodology will have indicated that fairly high demands are put on the specialist teachers of the mathematical, science and polytechnical school subjects. It is up to them to ensure that all healthy children achieve the aims of the instruction and that all children can develop their talents fully. This is only possible if initial and in-service teacher training equips teachers adequately. The initial teacher training for the intermediate and secondary levels of the *POS* has been carried out since 1982 (or 1983 in some cases) in a five-year university-level course at pedagogical colleges and universities according to a plan of study authorized by the Ministry of Higher Education and the Ministry of Public Education and obligatory for all teacher-training institutions. It is geared to the *POS* aims, content and methods of subject instruction. As a rule, teachers are trained in two subjects (called 'subject-combination') with equal rights as to the amount and quality of training. Graduates are qualified teachers. Teachers for the polytechnical subjects, however, are not trained in a second discipline because their course requires a much wider range of study. Pre-1982 training involved a four-year course, with a main and a subsidiary subject. The latter was treated in less depth and width, and accounted for fewer hours than did the main subject. Since teaching does not distinguish between main and subsidiary subjects, and because, by then, the economic development of the German Democratic Republic provided and guaranteed the material and personnel preconditions, a transition began in 1982 to a five-year training course which allowed a quantitative and qualitative improvement in teaching in schools. To give an idea of how teachers of mathematics, science and polytechnical instruction are trained, preparation for the subject combination biology/chemistry will be discussed. Not all details of the study plans can, of course, be given: the main features are similar for other subject combinations in the area of science.

Trainee teachers who are preparing themselves to teach *biology and chemistry* study the bases of these sciences for a total of about 2,000 periods. These naturally take up most of the available time. The content and method used in the training, except for a few items which are special to the teaching profession, are basically the same as for the training at colleges and universities for other professions. So, a close combination of tuition and research is common. At pedagogical colleges, nationally and internationally renowned scientific results have been achieved in close co-operation between professors, senior lecturers, academic staff and students. In biology, training is given in the fields of botany, zoology, general biology, microbiology, ecology and protection of the environment, as well as in the history of biology. Training in chemistry includes general chemistry, inorganic chemistry, organic chemistry, physical chemistry, technological chemistry and the history of chemistry. Training in the various disciplines takes place as a rule with the theoretical and practical work closely combined. Within the 2,000 periods available, some 700 periods are given over to practical training. In chemistry, practical laboratory training aims at introducing students to the necessary techniques, enabling them to study types of reactions, to carry out preparations and analytical tasks, and to learn the methods of physical chemistry. Technological chemistry involves visits to large chemical enterprises in order to familiarize students with the technological organization of chemical processes and related national economic aspects. In biology, practical laboratory training deals with working methods and techniques in the fields of cytology, histology, morphology, physiology, microbiology and biochemistry. In field work, selected working methods are practised in various ecological systems. The close combination of theoretical and practical training equips the students with the necessary prerequisites for a teaching career.

A basic course in the *social sciences* is important in the training of subject teachers. The ability to explain the association of mathematics, science and polytechnical instruction with life and with issues of social development, to describe the relationships among science, technology and production, to explain trends in scientific and technological progress and in economic strategy and scientific, social and philosophical connections, all require future teachers to have a sound education in the social sciences. Apart from this, a scientific-based world outlook is considered to be an imperative part of a university graduate's general education. Thus, the basic course in social sciences, the study of Marxism-Leninism (300 periods), forms part of the training during the first four years. It includes the fields of dialectical and historical materialism, the political economies of socialism and capitalism, scientific communism, and the history of the working-class movement. Finally, the students can extend their knowledge in one of the several special courses available. Students of mathematics, science and polytechnical subjects often choose a special course on philosophical aspects of the sciences or on special problems of political economy, because these courses provide effective support for the philosophical or economic education in teaching.

Students of mathematics, science and polytechnical subjects often choose a special course on philosophical aspects of the sciences or on special problems of political economy, because these courses provide effective support for the philosophical or economic education in teaching.

Training in the educational sciences, which is essential for a teacher, can be subdivided into four stages: basic pedagogical training, bases of psychology, teaching methodology, and practical training at a school. All in all, this includes from the first to the fourth year about 600 periods. It is concluded in the fifth year with twenty-seven weeks of practical training at a school. Training in the educational sciences and, consequently, the entire course from the first to the fifth year are linked in various ways with teaching practice in schools. The unity of theory and practice in the process of teacher training has proved valuable for understanding the function of teaching and education in the general school, for the development of the ability to work systematically with children and adolescents, and of pedagogical skills, and, not least, motivating study and familiarizing future teachers with the daily demands they will face.

Basic pedagogical training (120 periods) covers the history of education, the fundamentals of pedagogy, the theory of education and didactics. Students are introduced to policy as regards education and training at the socialist school, the general tasks of a teacher and educator, and the principles of organizing teaching. Didactics acts as a linking element to the specific teaching methods which arise in the course of instruction in a particular subject. During this phase, students are active in extracurricular work with students at schools in various ways (mainly in children's and youth organizations and in interest groups). In second year, they have some practical tasks, such as observing classroom teaching and evaluating it, three weeks practical work in a children's summer camp.

Closely linked with basic pedagogical training is the study of the *bases of psychology* (120 periods). This includes general personal psychology, developmental psychology, learning and educational psychology, and learning and behavioural disturbances, as well as diagnostics.

Training in the *methods of teaching* (400 periods in third and fourth year), is based on basic pedagogical and psychological training. It is carried through in a close combination of theoretical and school-practice training. During theoretical training the students are familiarized with: the aims of training and education in the particular school subject; the content and structure of the course on the basis of the syllabus and in connection with the aims; the organization of teaching in the particular subject with regard to the unity and interaction of aims, content and method; the organizational and methodological implementation of subject teaching under present conditions; the implementation of fundamental educational and teaching tasks; teaching aids and their efficient use; typical classroom situations and their methodological organization; the theory and practice of planning subject teaching; and the particularities of optional instruction.

Practical training in third and fourth year involves practical work at a school. Under the direct guidance of a member of the academic staff for methods of teaching chemistry or biology, the students work in small groups in subject teaching in schools. After thorough preparation with the respective member of the academic staff in charge, they take turns in practical teaching, while the other students of the group sit in on these classes and afterwards evaluate their experiences. By the end of fourth year, each student will have taught five periods in each subject of his or her combination.

Because the students of science subjects receive comprehensive experimental training during periods of practical work, they are thoroughly prepared to handle the particular techniques and methods of experiment and other technical operations in teaching. They are given the opportunity to carry out all important experiments during this practical period in the way required in the classroom. In doing so, the technique of the school experiment is always linked with considerations of how to use the experiment in the methodological organization of instruction.

The climax of practical training is the *practical year at a school* under the guidance of an experienced subject teacher, the fifth year of the teacher-training course. The trainee teachers teach their subjects an increasing number of periods, thus perfecting their pedagogical and methodological skills. They observe lessons given by experienced teachers. They critically discuss the educational process. They thus acquire advanced experience of school practice. They acquire experience in the pedagogical guidance of a class and participate in all activities which are part of the teaching profession in the day-to-day practice of school life. Thus, at the end of their training, they have the best possible qualifications for taking over the full responsibilities of teachers and educators as subject teachers in the socialist school.

This short survey of the preparation of subject teachers for the requirements of mathematical, science and polytechnical instruction at the polytechnical secondary school in the German Democratic Republic cannot be concluded without mentioning compulsory training (about 200 periods) in the course of which the final paper has to be written. In all parts of the training, the principle of the unity of instruction and research is being put into effect, so that the students can choose their compulsory training in one of the academic fields. This training starts in the sixth semester, with a build up of knowledge and skills in a specialized area of a particular academic field. The students are prepared methodically for independent work in a scientific problem. Under the guidance of a scientist, they participate in a research project in an

academic field. Many take part in research work prior to the compulsory training to familiarize themselves with scientific methods.

Enabling teachers to fulfilling the high requirements of subject teaching does not terminate with the end of teacher-training. Continuous and systematic in-service training of all teachers is needed because of scientific and technological progress, of expanding findings in the field of educational sciences, of advancing experience in the practice of subject instruction and changes in syllabuses. In the German Democratic Republic, this in-service training is provided in a system of courses, two of which (each of 30 periods) each teacher has to attend within a cycle of years. In such courses, scientists impart their latest findings in their subject or in their special field of education. The teachers perfect their knowledge of the social sciences. Experienced teachers share their experience of the organization of instruction and discuss with their colleagues possible variants of the organization of teaching. This in-service training is run by county centres for in-service training of the departments of public education in county councils, so that, in this respect too, close interaction between theory and practice is achieved.